Existing Water Quality – Reach Wide Summary

2000-2003 Reachwide Existing Water Quality for the Lower Delaware River														
Parameter	n	Mean	SD	SE	95% CI of Mean		Median	95% CI of Median		10%ile	25%ile	50%ile	75%ile	90%ile
Ammonia NH3-N	274	0.048	0.040	0.002	0.044	0.053	0.025	0.025	0.030	0.025	0.025	0.025	0.060	0.108
CaCO3 Alkalinity	350	39.7	20.7	1.1	37.5	41.8	36.0	34.0	39.0	20.0	27.0	36.0	50.0	59.0
CaCO3 Hardness	350	54.8	20.1	1.1	52.7	57.0	52.0	48.0	59.0	30.0	38.0	52.0	72.5	79.0
Chloride	347	13.8	7.1	0.4	13.0	14.5	15.0	14.0	16.0	1.9	10.0	15.0	19.8	22.0
Chlorophyll A mg/m3	306	2.69	2.33	0.13	2.43	2.95	2.14	2.00	2.67	0.50	0.97	2.14	3.60	5.34
Dissolved Oxygen	347	8.8	1.1	0.1	8.6	8.9	8.7	8.6	8.8	7.4	7.9	8.7	9.5	10.3
Dissolved Oxygen % Saturation	347	97.7%	8.4%	0.4%	96.8%	98.6%	96.4%	95.6%	97.0%	89.1%	92.3%	96.4%	101.3%	108.1%
E. coli (mean is geometric)	270	33					30	22	36	4	10	30	80	280
Enterococcus (mean is geometric)	309	61					58	48	70	8	20	58	180	530
Fecal Coliform (mean is geometric)	309	61					56	48	70	8	20	56	142	530
Nitrate NO3-N	331	1.108	0.567	0.031	1.047	1.169	1.010	0.970	1.090	0.572	0.750	1.010	1.320	1.558
Orthophosphate PO4-P	295	0.045	0.033	0.002	0.041	0.049	0.040	0.030	0.040	0.005	0.020	0.040	0.070	0.090
pH	349	7.64	0.48	0.03	7.59	7.69	7.60	7.53	7.61	7.08	7.36	7.60	7.90	8.20
Phytoplankton Biomass mg/m3	306	180	156	9	163	198	143	134	179	34	65	143	241	358
Specific Conductance umhos/cm	350	159.0	50.5	2.7	153.7	164.3	156.5	142.0	164.0	94.1	117.0	156.5	204.3	229.0
Total Dissolved Solids	319	133.7	40.0	2.2	129.3	138.1	130.0	130.0	140.0	86.0	110.0	130.0	160.0	170.0
Total Nitrogen : Total Phosphorus ratio	270	20.2	11.4	0.7	18.8	21.5	17.3	16.8	18.2	10.9	13.2	17.3	24.4	30.8
Total Kjeldahl Nitrogen	270	0.479	0.568	0.035	0.411	0.547	0.340	0.310	0.380	0.080	0.190	0.340	0.583	0.957
Total Nitrogen	270	1.474	0.704	0.043	1.389	1.558	1.410	1.300	1.470	0.826	1.025	1.410	1.763	2.189
Total Phosphorus	278	0.091	0.062	0.004	0.084	0.098	0.080	0.070	0.090	0.030	0.050	0.080	0.120	0.140
Total Suspended Solids	319	9.5	19.2	1.1	7.4	11.6	4.5	4.0	5.0	1.0	2.5	4.5	8.5	18.0
Turbidity	350	5.7	12.1	0.6	4.5	7.0	2.6	2.2	3.1	0.8	1.2	2.6	6.0	10.0
Water Temperature F	350	69.9	7.8	0.4	69.1	70.7	71.1	69.1	72.3	59.3	64.1	71.1	75.9	80.6

Table 4. Reach Wide Existing Water Quality of the Lower Delaware River (Preliminary 2000-2003 monitoring data).

Table 4 summarizes reach wide Existing Water Quality in the Lower Delaware River. The 2000-2003 data set is the basis for this table, which will be supplemented by additional 2004 data. Although useful for general characterization, and to note site differences from the reach as a whole, Special Protection Waters rules would be difficult and unfair to implement using a reach wide table such as this. Natural water quality changes drastically from Portland to Trenton. Breidt and Boes (1989) recommended that reach wide criteria should not be used in the Middle Delaware because water quality at Port Jervis differed so much from that at the Delaware Water Gap. Based on the data set, they also recommended a site specific, non-parametric approach to water quality protection (Breidt et al. 1992). Perhaps these results were unavailable to resource managers at the time, but the DRBC Staff Report on Scenic Rivers Water Quality Protection (1990) contains no mention of site specific or non-parametric targets. EWQ at individual sites was not equal throughout the Middle Delaware, and it is even less so in the Lower Delaware. Site-specific targets (defined using values shown in **Appendix A**) are the proper means to fairly apply rules based upon EWQ, and to confidently distinguish measurable changes to EWQ.

Lower Delaware reach wide data were compared with Middle Delaware EWQ from DRBC Water Quality Regulations (1996). The Lower Delaware contains higher concentrations of hardness, alkalinity, TDS and specific conductance. Limestone effects and urbanization can cause these increased concentrations. Lower Delaware and Middle Delaware River fecal coliform bacteria, dissolved oxygen, ammonia, pH, and TSS concentrations are similar. Nitrate, TKN, and Total Phosphorus concentrations are much higher in the Lower Delaware. Lower Delaware Nitrate concentrations are 5 times, TKN concentrations are twice, and Total Phosphorus concentrations are 3 times that of the Middle Delaware.

Such comparison may be unfair due to natural longitudinal water quality changes, as stated earlier. However, the results indicate that the Lower Delaware may be at risk of eutrophication due to excess nutrient inputs. Nutrient levels do not render the Lower Delaware unsuitable for its uses, but unknown at this time is what effect increased nutrient levels produce in the Delaware River. Nutrient dynamics must be investigated in the river system, and nutrient criteria must be established. Meanwhile, protection of water quality at existing levels through Special Protection Waters status is recommended.

Wastewater and Stormwater Represented in Existing Water Quality

Appendix E contains an inventory of municipal, institutional, and industrial wastewater dischargers of over 100,000 gallons per day to streams in the Lower Delaware watershed. The wastewater from these facilities is included in the definition of existing water quality, and these facilities as permitted would not be subject to additional treatment requirements set forth in DRBC's water quality rules for Special Protection Waters. Only new and expanded discharge facilities would be subject to such rules. In terms of average monthly wastewater effluent flow during the 2000-2003 study period, Pennsylvania dischargers operated at 71% of their overall permitted flow, and New Jersey dischargers operated at 66% of their overall capacity.

Existing water quality might or might not measurably change if all of the permitted dischargers increase their effluent rate to 100% of their capacity. As defined during the 2000-2003 study period, existing water quality reflects a very broad range of discharge situations from extreme low flow conditions to relatively high flow conditions, when most dischargers operated at far beyond normal flow rates. Thus the statistical definition of existing water quality includes such cases of high flow events. Under such conditions the dischargers achieved their permitted water quality limits without permit violations or severe increases in the rate of pollutant loading to the Delaware River. A few treatment facilities continue to experience infiltration and inflow (I and I) problems related to storm events, which forces the facility to treat stormwater in addition to sanitary sewage flow. Maintenance of I and I is an excellent step toward ensuring that existing water quality is maintained or improved.

Of much more concern is non-point source water pollution, or that caused by stormwater runoff. The increase in non-point source pollution associated with future growth and development is very likely to measurably change existing water quality if it increases unmanaged. It is expected, however, that existing water quality will continue to <u>improve</u> even as the wastewater treatment facilities grow toward their full capacity. New stormwater rules and policies are taking effect in New Jersey and Pennsylvania, efforts to improve riparian buffer zones continue to grow and evolve, residential and business stormwater management practices are improving, and education of municipal officials and the general public on stormwater issues is becoming more widespread. These powerful tools improve water quality and allow for growth and development.

To ensure that existing water quality is maintained or improved, the control point monitoring approach should be used to document cumulative effects of combined point source and non-point source water management. The water quality targets at Boundary Control Points must not be exceeded, or water quality of the Delaware River will degrade. The targets may also be used as a reference to quantify trends and improvements in water quality resulting from combined efforts to manage dischargers and non-point source pollution in each watershed.

Existing Water Quality vs. Standards – Site-Specific Summary Analyses

Table 5 summarizes EWQ status versus standards. Each small cell in the matrix represents a water quality comparison to the most stringent criteria or guidelines available. 14 chemical parameters were statistically compared to standards for 9 river and 15 tributary sites. Three biological metrics were calculated using the 2001 Delaware River macroinvertebrate data set and examined versus the most stringent available targets. No criteria exist for 10 of the 24 Lower Delaware parameters.

Delaware River results indicate that existing water quality is generally better than criteria levels, with the exception of enterococcus bacteria. Of 153 possible comparisons (9 sites, 14 chemical parameters and 3 biological metrics), 94% showed that EWQ is better than or meets criteria. EWQ based targets can provide additional protection of existing water quality for most sites and parameters.

A few parameters exceeded criteria due to natural conditions. Total phosphorus concentrations exceeded

Table 5. Lower Delaware River Existing Water Quality Versus Standards.

EWQ Better	EWQ is better than criteria
EWQ Better Except for High Flow	EWQ is better than criteria except during high flow events (E. coli, Fecal coliform bacteria)
Criteria exceeded by natural conditions	EWQ is evidenced to be naturally higher than criteria (TDS, pH)
TP criterion exceeded but use not limited	EWQ higher than NJ 0.1 criterion, but suitable for designated uses (Total Phosphorus)
EWQ Exceeds Criteria	EWQ Exceeds Criteria for >10% of Samples
Not Assessed	Not Assessed

Parameter	Del @ Portland	Del @ Belvidere	Del @ Easton	Del @ Riegelsville	Del @ Milford	Del @ Bulls Island	Del @ Lambertville	Del @ Washington Xing	Del @ Trenton	Most Stringent Criterion
Bio - EPT (N=1)	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	UPDE EWQ
Bio - HBI (N=1)	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	NJ 4.0
Bio - Diversity (N=1)	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	UPDE EWQ
Dissolved Oxygen	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	5 (all)
pH	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Criteria exceeded by natural conditions	EWQ Better	EWQ Better	Criteria exceeded by natural conditions	6.5-8.5 (NJ)
Water Temperature F	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Seasonal (PA)
Turbidity	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	15 (NJ)
CaCO3 Alkalinity	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Min 20 (PA)
Chloride	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	250 (all)
Nitrate NO3-N	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	10 (PA,NJ)
Ammonia NH3-N	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Formula (PA,NJ)
Total Phosphorus	EWQ Better	EWQ Better	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	0.1 (NJ)
Total Dissolved Solids	Criteria exceeded by natural conditions	Criteria exceeded by natural conditions	Criteria exceeded by natural conditions	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	120/256 (DRBC)
Total Suspended Solids	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	40 (NJ)
E. coli geometric mean	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	126 (EPA)
Fecal Coliform geometric mean	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	200,400 (all)
Enterococcus geometric mean	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	33,61 (NJ)
Biocriteria	NO STANDARD									None
CaCO3 Hardness	NO STANDARD									None
Chlorophyll A mg/m3	NO STANDARD									None
Dissolved Oxygen % Saturation	NO STANDARD									None
Orthophosphate PO4-P	NO STANDARD			**EWQ definition would create targets for parameters without standards**						None
Phytoplankton Biomass mg/m3	NO STANDARD									None
Specific Conductance umhos/cm	NO STANDARD									None
Total Nitrogen : Total Phosphorus ratio	NO STANDARD									None
Total Kjeldahl Nitrogen	NO STANDARD									None
Total Nitrogen	NO STANDARD									None

New Jersey's 0.1 mg/l criterion at several Delaware River locations, but did not render the Delaware River unsuitable for designated uses according to NJDEP guidance on interpretation of the total phosphorus standard (NJDEP 2003). More than 10% of total dissolved solids concentrations exceeded the DRBC stream quality objective at 3 Delaware River locations, but this was determined to be the result of limestone influences at low flow and thus a natural condition. More than 10% of pH samples exceeded the DRBC stream quality objective at 2 Delaware River locations due to natural plant activity during extended periods of low flow. Fecal coliform and E. coli concentrations exceeded criteria during high flow events, but geometric mean concentrations were well below criteria levels at all Delaware River locations.

Enterococcus bacteria counts (**Figure 8**) exceeded New Jersey's freshwater criterion of 33 colonies per 100 ml at every river and tributary site. Only the Delaware River sites had enterococcus counts of less than 100 colonies per 100 ml. Geometric mean counts ranged from 37 at Calhoun Street Bridge to 174 at Easton. If enterococcus criteria existed for Delaware River Zones 1D-1E, they would be used to determine the Delaware River's suitability for primary contact recreational use. At the recommended criteria levels, the Lower Delaware and all of its tributaries would not be suitable for such use. Low flow samples exceeded criteria nearly as frequently as high flow samples.

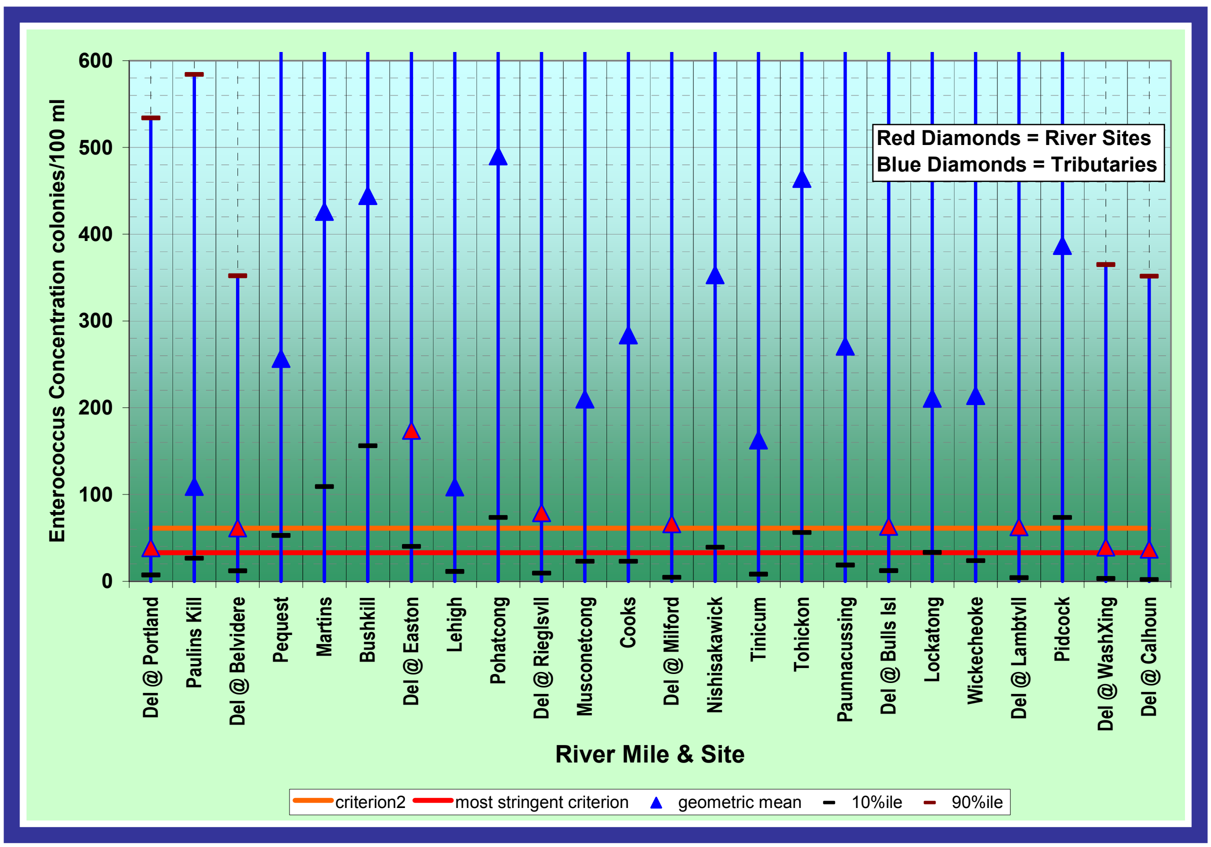


Figure 8. Enterococcus Geometric Mean Concentrations in the Lower Delaware River and its Tributaries. Blue lines extending above 600 colonies per 100 ml indicate that the 90th percentile of these bacteria counts are higher than the range of this display. The most stringent criterion is New Jersey's 33/100ml geometric mean and single sample maximum of 61/100ml.

Figure 9 shows median Total Phosphorus concentrations in the Lower Delaware and its tributaries. In the Delaware River, TP concentrations remain low (around 0.05 mg/l) until the Lehigh River confluence. Not only were the highest TP concentrations found in the Lehigh, but also the Lehigh is the second largest tributary to the Delaware River. The Total Phosphorus load entering the Delaware River from the Lehigh

River is enormous. From this point down to Trenton, Delaware River TP concentrations remain above the most stringent criterion level of 0.1 mg/l established by New Jersey DEP. At present, no Total Phosphorus criteria exist in DRBC or PADEP rules for this zone of the river. **Figure 9** also shows that the 0.1 mg/l TP criterion is exceeded in more than 10% of samples taken from the following additional tributaries: Pequest, Martins, Pohatcong, Musconetcong, Nishisakawick, Paunnacussing, Lockatong, Wickecheoke, and Pidcock. In all of these streams, median concentrations were significantly higher than that of the neighboring Delaware River sites (p=0.05). Since no criteria exist other than in New Jersey, an appropriate management decision would be to use EWQ and Special Protection Waters rules to restore water quality to levels below 0.1 mg/l. This would require significant phosphorus load reductions from intrastate waters.

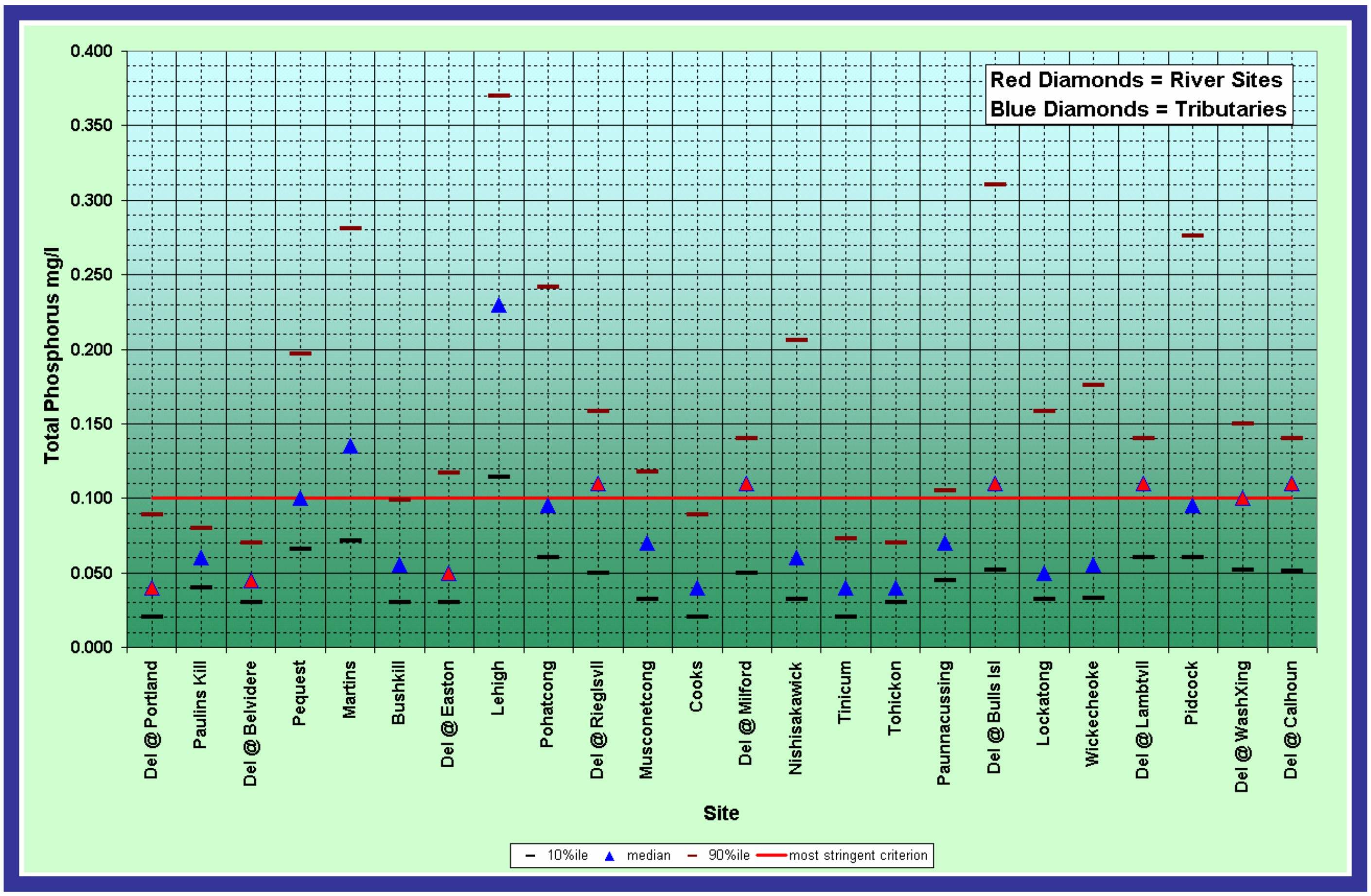


Figure 9. Total Phosphorus concentrations in the Lower Delaware River and tributaries. The most stringent criterion is New Jersey's 0.1 mg/l limit. The Lehigh River significantly increases TP concentrations in the Lower

A third water quality problem in the Lower Delaware River and its tributaries is E. coli bacteria pollution. Figure 10 shows geometric mean concentrations, 10th and 90th percentiles, and the federal guideline geometric mean level of 126 colonies per 100 ml. No E. coli criteria exist in DRBC, Pennsylvania or New Jersey rules at present. However, criteria development is being considered since the U.S. EPA recommended that E. coli and enterococcus criteria are better indicators than fecal coliforms of water quality suitability for primary contact recreation. Geometric mean values in the Delaware River are better than the guideline threshold at all sites. However, more than 10% of samples exceed the guideline at every site, a violation frequency that may indicate a problem. **Table 6** shows that Delaware

River guideline violations can be explained by high flow events. E. coli criteria should be developed for the Lower Delaware. Swimmers should be advised of E. coli risks during high flow events.

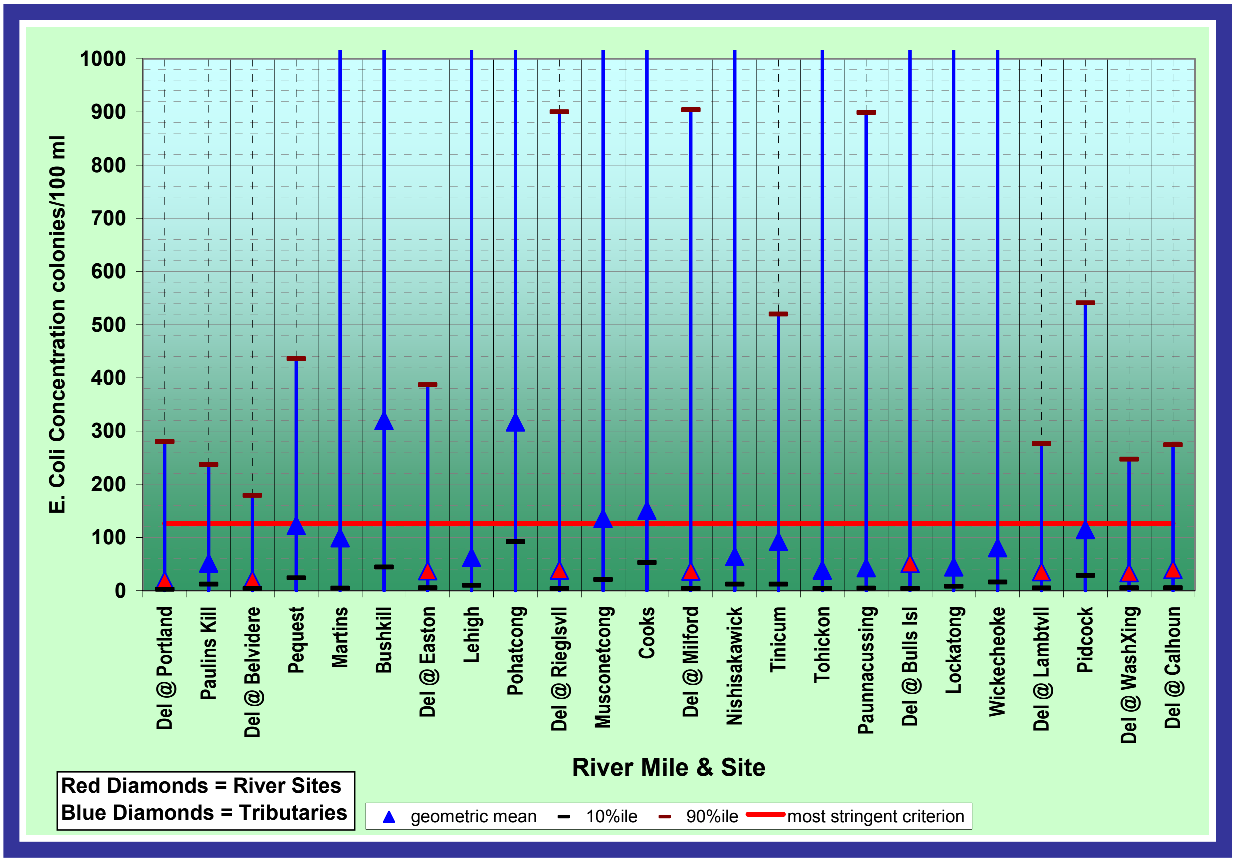


Figure 10. E. coli geometric mean concentrations in the Lower Delaware River and Tributaries. Also displayed are 10th and 90th percentiles and the red line is a recommended federal guideline geometric

Table 6. Median E. coli concentrations by flow percentile.

Flow Percentile	N	Median E. coli	10th %ile	to	90th%ile
<10th	32	12	4	to	47
10th to 25th	50	16	4	to	79
25th to 50th	53	20	3	to	243
50th to 75th	66	24	5	to	280
75th to 90th	45	50	12	to	2,000
>90th	24	200	54	to	920

The fourth potential Lower Delaware water quality problem is fecal coliform bacteria pollution **(Figure 11)**. DRBC and state criteria set a 30-day geometric mean concentration of 200 colonies per 100 ml. The required sampling frequency of 5 samples per 30-day period was not practiced by DRBC. The geometric mean of LDMP data represents 10 samples per May-September period, known as a summer seasonal geometric mean. Water quality rules also state that no more than 10% of samples may exceed a maximum concentration of 400 colonies per 100 ml. **Figure 11** shows that all Delaware River geometric mean values were much better than the criterion. Tributaries worse than the 200/100ml criterion were Martins;

Bushkill; Pohatcong; Musconetcong; Cooks; Tinicum; and Pidcock. Evaluation of the frequency of violations of the 400/100ml criterion revealed that all sites except for the Delaware River at Belvidere, Lambertville, and Washington's Crossing exceeded the criterion for more than 10% of samples. Most violations occurred during high flow events **(Table 7)**.

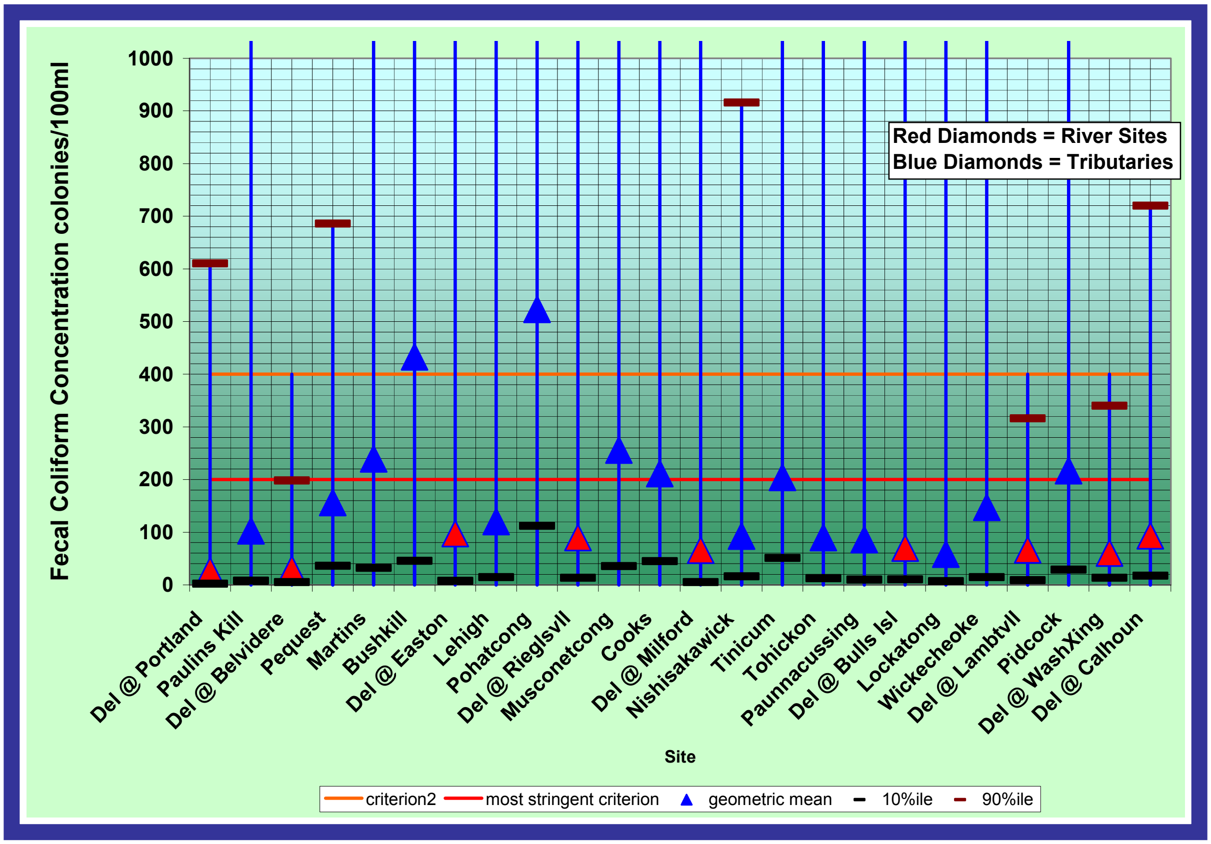


Figure 11. Fecal coliform geometric mean concentrations in the Lower Delaware River and Tributaries. Also displayed are 10th and 90th percentiles. The red and orange lines are DRBC criteria levels of 200 colonies per 100 ml 30-day geometric mean, and 400 colonies per 100 ml single sample maximum.

Table 7. Lower Delaware River Fecal Coliform Median Concentrations by Flow Percentile.

Flow Percentile	N	Median Fecal Coliform	10^{th}%ile	to	90^{th}%ile
<10th	32	18	5	to	111
10^{th} to 25^{th}	55	50	5	to	130
25^{th} to 50^{th}	80	50	5	to	820
50^{th} to 75^{th}	66	52	16	to	461
75^{th} to 90^{th}	52	80	20	to	3,070
>90th	24	190	57	to	1,450

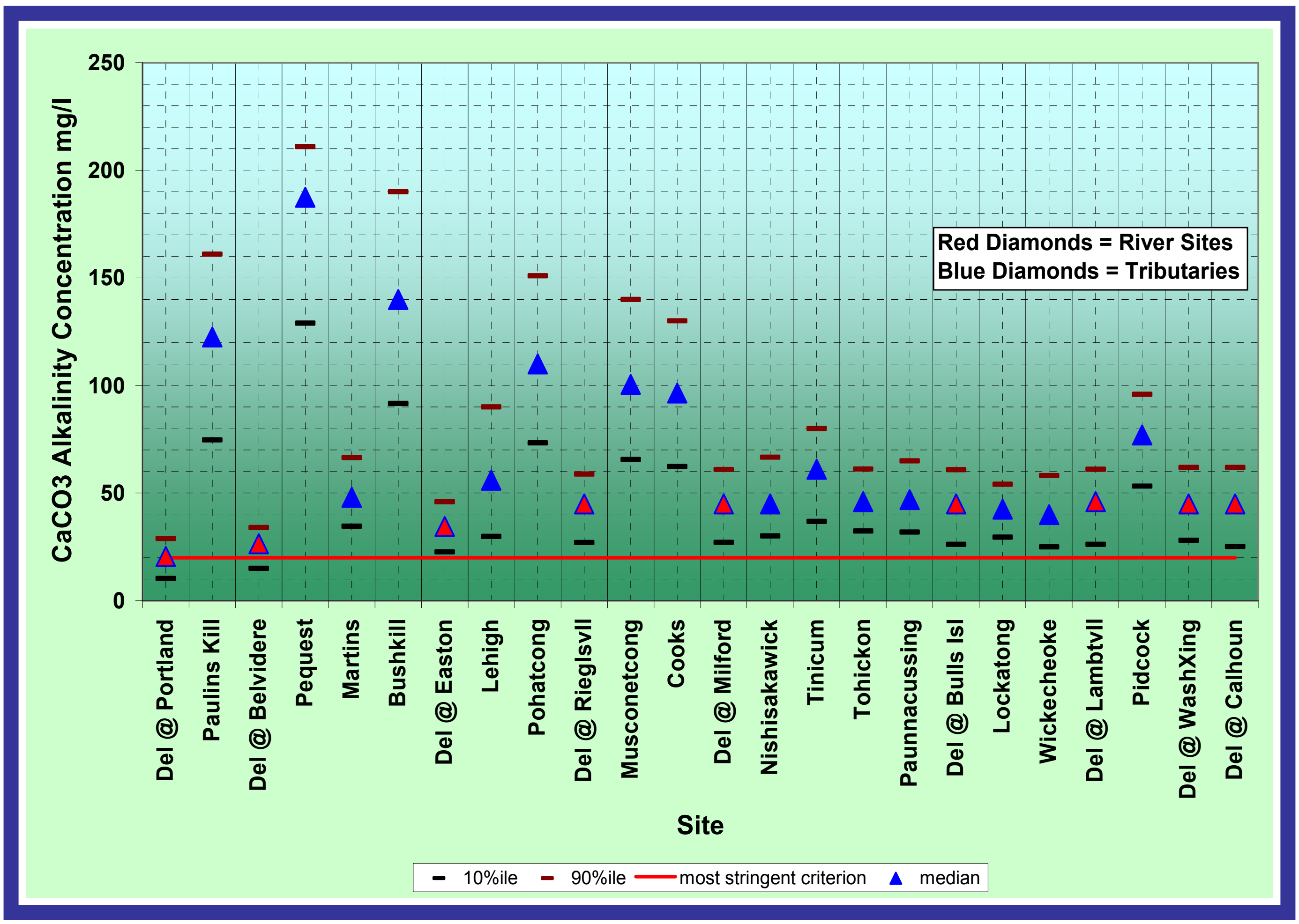
Existing Water Quality vs. Standards – Longitudinal Plots

The next several pages show longitudinal water quality plots of the Lower Delaware River and tributaries. Plots of parameters (alphabetically ordered) for which criteria have been established are shown in this section, and **Appendix B** contains similar representations of water quality constituents for which no criteria are established. EWQ targets should be created for all parameters.

Longitudinal plots show median concentrations; 10th and 90th percentiles of the data; and the most stringent criterion chosen from DRBC, Pennsylvania, or New Jersey standards. Tributary BCP's were statistically compared with upstream and downstream Delaware River ICP sites (**Appendix C**).

<u>Alkalinity as CaCO3</u>

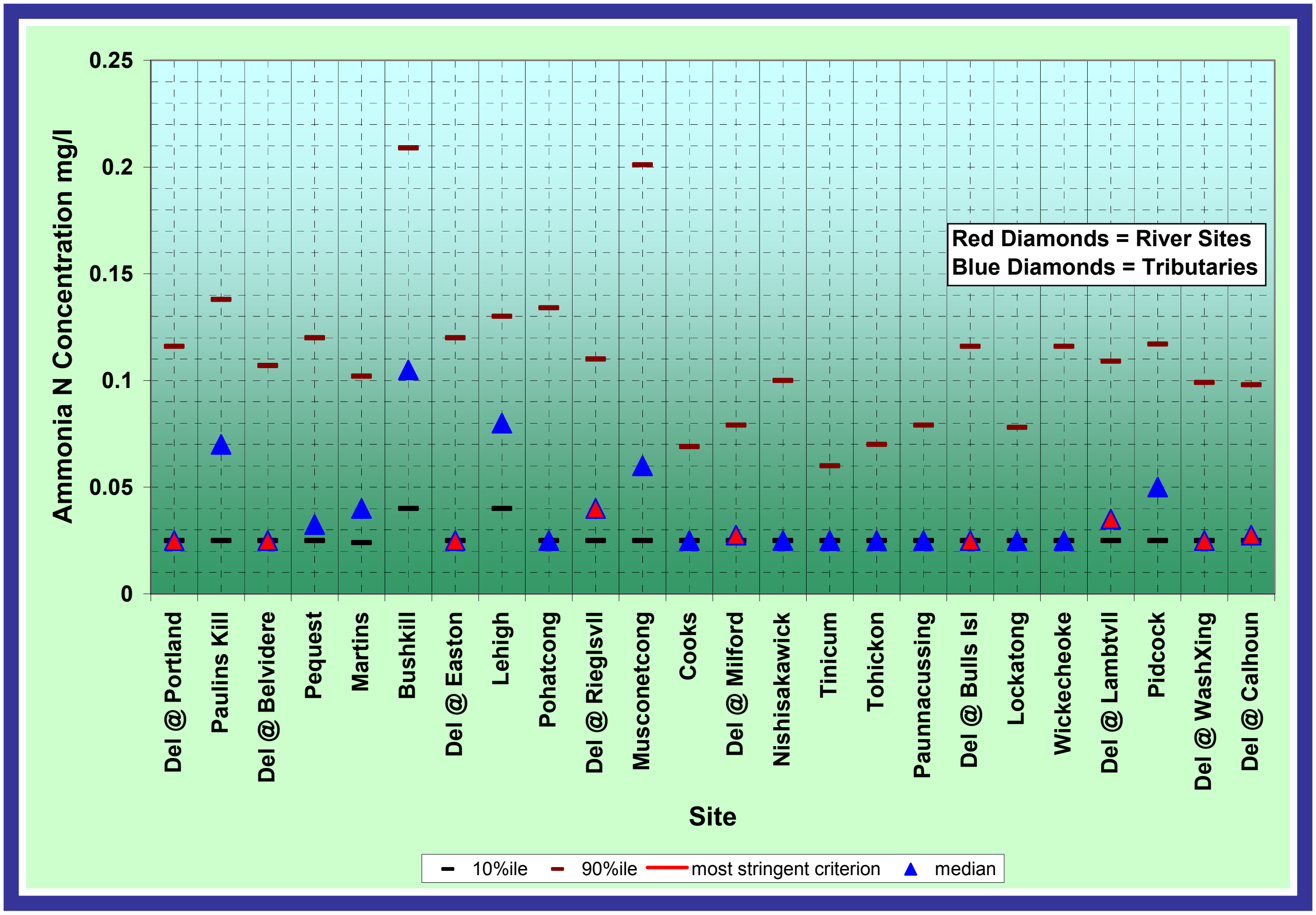
Figure 12. Lower Delaware Alkalinity vs. Standards.



The most striking pattern observed in **Figure 12** is that displayed by alkalinity concentrations of limestone streams. All tributaries in the northern part of the Lower Delaware contribute significant alkalinity to the Delaware River. Portland and Belvidere retain the low alkalinity characteristic of the Middle Delaware. All Delaware River sites downstream are significantly higher in alkalinity (p=.05).

Ammonia (Un-Ionized NH3-N)

Figure 13. Lower Delaware Ammonia Concentrations, Longitudinal Plot.

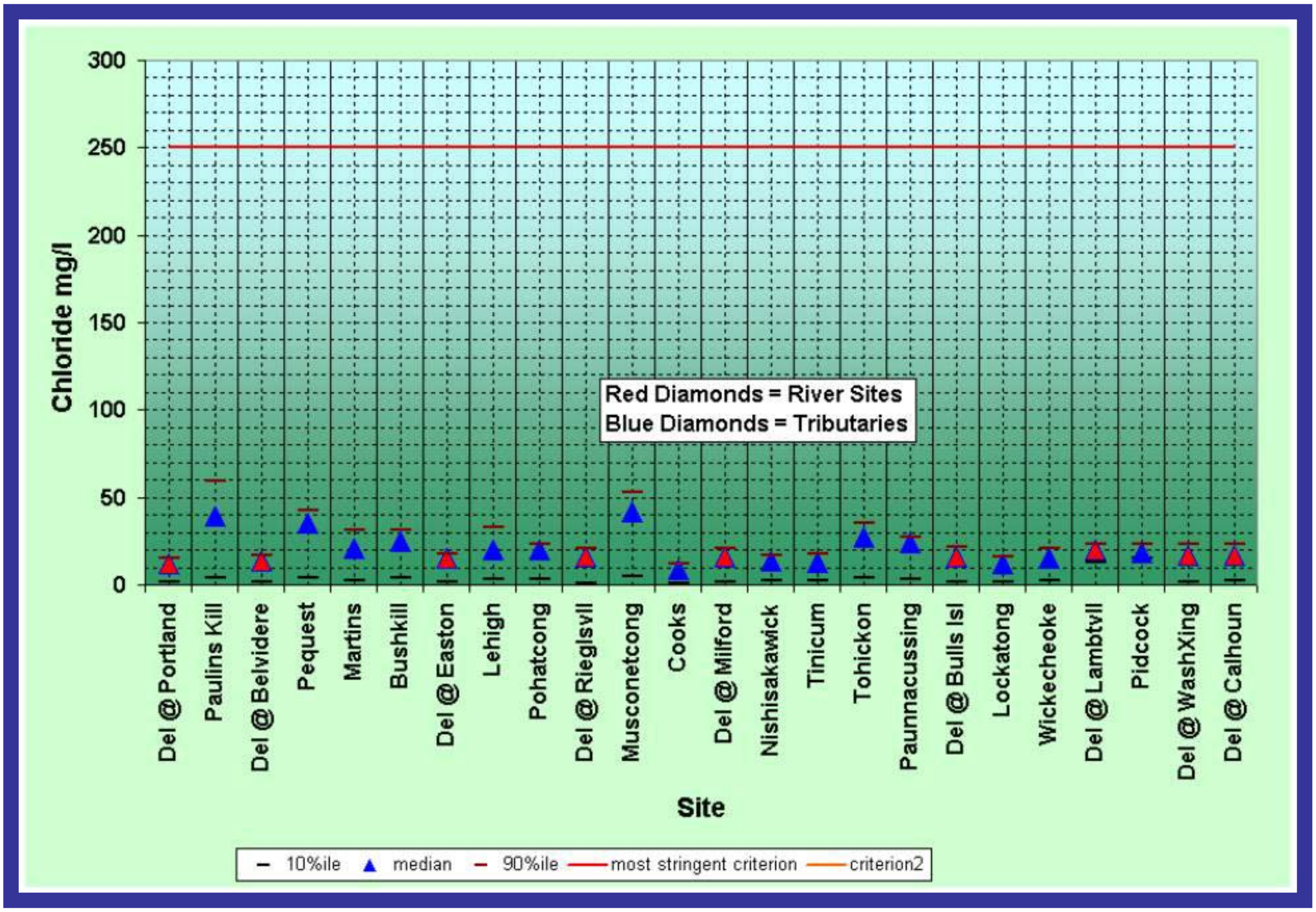


Un-ionized Ammonia (NH3-N) concentrations were compared with State criteria, which are complex formulae (see Pennsylvania and New Jersey water quality standards) that are difficult to display graphically. As calculated from this data set, ammonia criteria levels ranged from 0.001 mg/l to 4.697 mg/l. Each data value was compared to this temperature and pH dependent criterion, and the difference between the criterion level and the observed level was calculated. In the entire data set (n=713), only 5 instantaneous values exceeded criteria (a rate of 0.7%). The median departure of observed values versus criteria was (–0.718 mg/l), and the 97.5th percentile of departure was (–0.164 mg/l). This indicates that ammonia EWQ (which ranges from 0.02 mg/l to 0.42 mg/l) is much better than criteria.

Creation and use of EWQ Ammonia targets is recommended. In addition to target levels, a baseline should also be set for minimum number of non-detect values per site (MDL was 0.05 mg/l). There were a large number of non-detect values in the water quality data, which caused the pattern seen in **Figure 13** above, where median values nearly equal ½ of the MDL for many sites.

Chloride Concentration

Figure 14. Lower Delaware Chloride Concentrations, Longitudinal Plot.



When plotted against the 250 mg/l human health criterion, chloride concentrations in the Lower Delaware River and its tributaries appear miniscule **(Figure 14)**. Establishment of EWQ targets would provide an additional level of protection to ambient water quality for this parameter.

Dissolved Oxygen

Figure 15. Lower Delaware Dissolved Oxygen Concentrations, Longitudinal Plot.

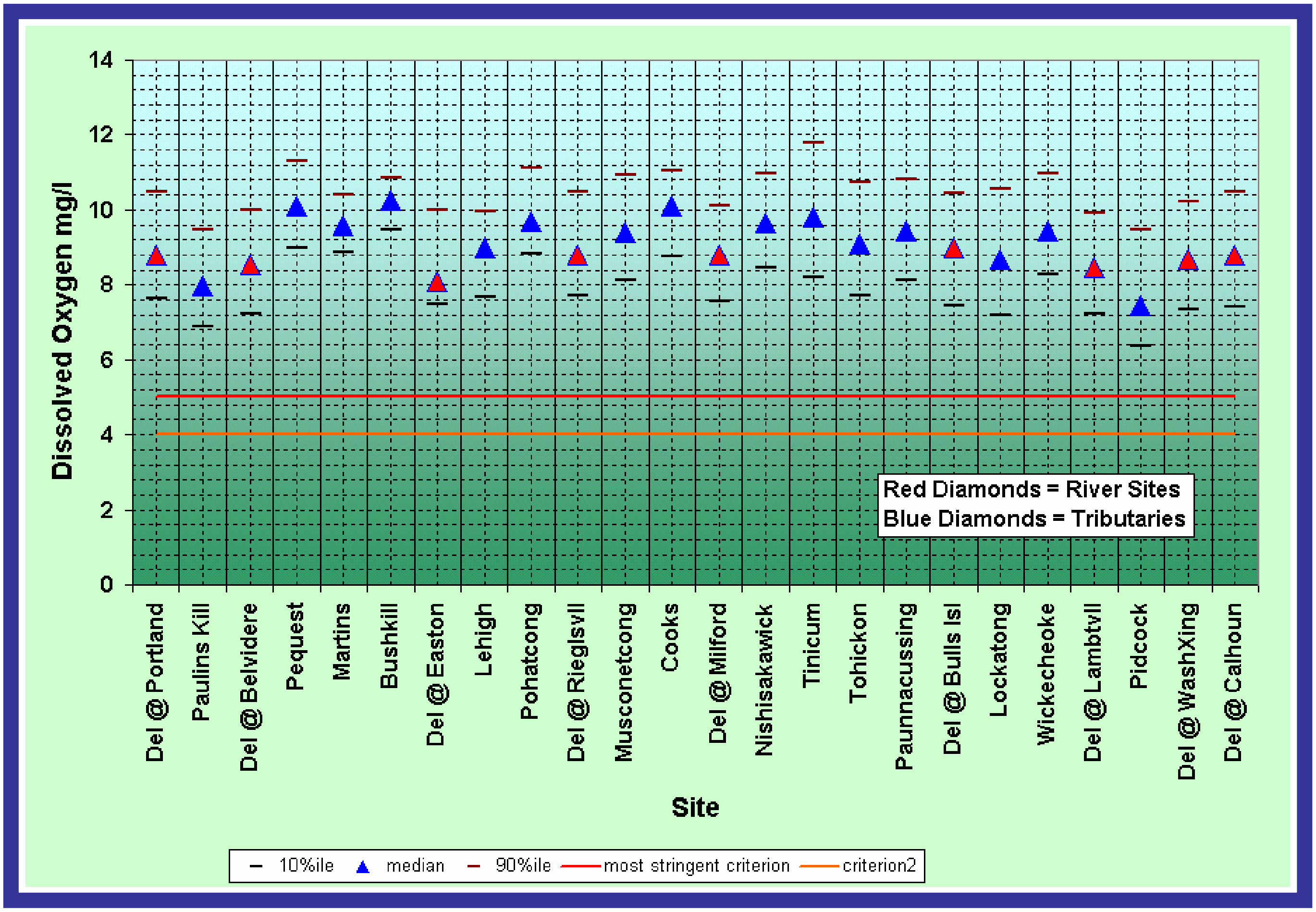


Figure 15 displays median dissolved oxygen concentrations in the Lower Delaware River and its tributaries. Most of these samples were taken near mid-day, so these concentrations approximate maximum daytime values. These results indicate existing water quality is far better than criteria. To verify these findings using data taken around the clock, **Figure 16** displays continuous results taken from the U.S. Geological Survey monitor on the Delaware River at Point Pleasant, PA.

Dissolved Oxygen – Continuous Monitor at Point Pleasant, PA

Figure 16. Point Pleasant Dissolved Oxygen Concentrations 2000-2003.

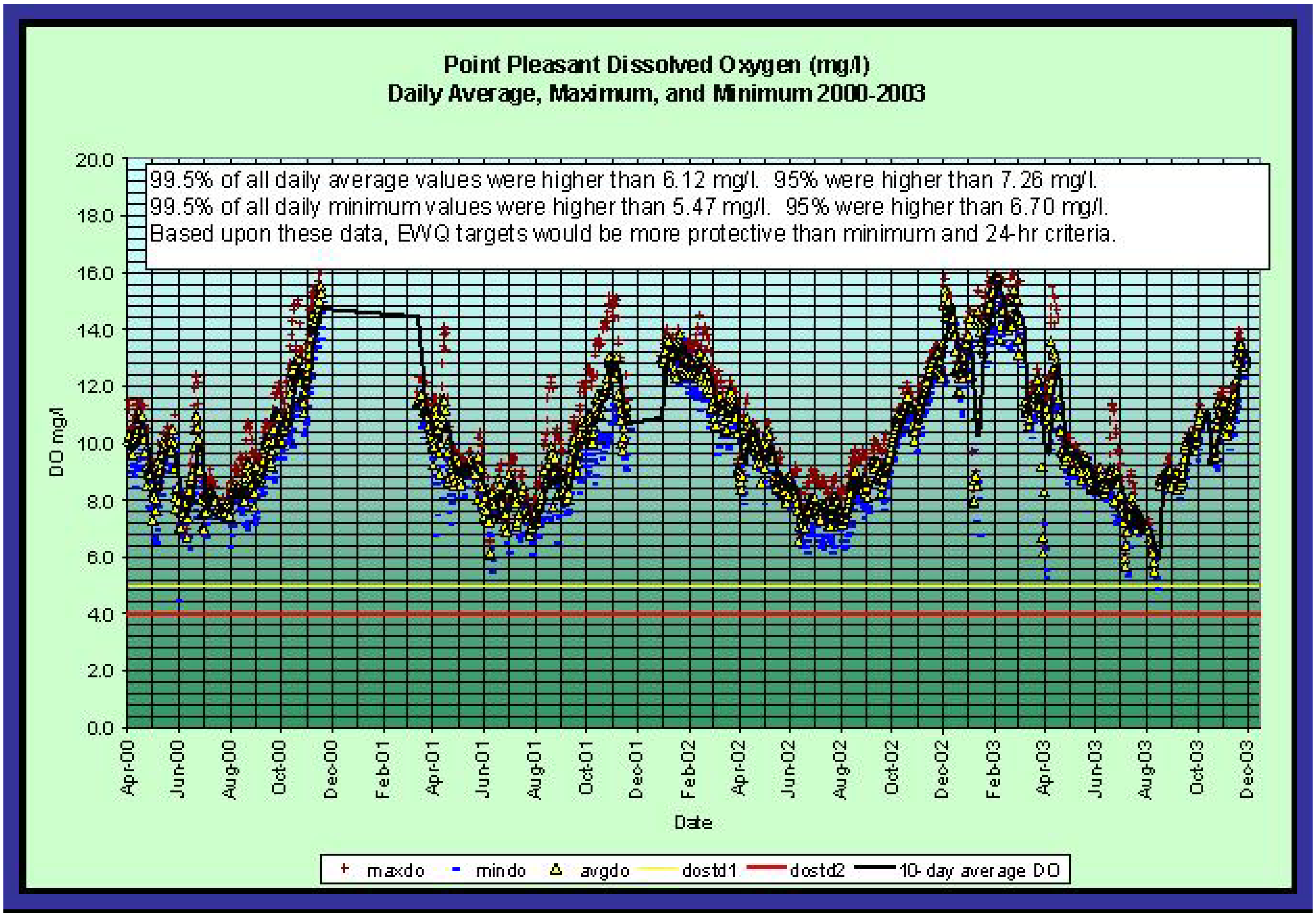


Figure 16 shows that EWQ is much better than criteria, verifying the mid-day instantaneous sample results taken by the LDMP. Even nighttime minimum dissolved oxygen during a severe drought very rarely fell below 5.5 mg/l. The daily range of dissolved oxygen change (daytime average DO versus nighttime average DO) was tested to determine whether elevated total phosphorus concentrations produced an undesirable effect upon aquatic plant activity. According to NJDEP guidance for interpretation of the phosphorus rule, a daily swing of more than 3.0 mg/l is one of the factors considered to render the Delaware River unsuitable for designated uses. This occurred only 1% of over 1,100 days tested. Another DO test for the phosphorus rule is the frequency of days below the minimum DO criterion level. At Point Pleasant, Delaware River DO concentrations never fell below criteria levels. These results indicate that phosphorus concentrations, though elevated above the 0.1 mg/l criterion, do not produce an undesirable effect upon aquatic plant production in the Lower Delaware.

Nitrate (NO3 as N)

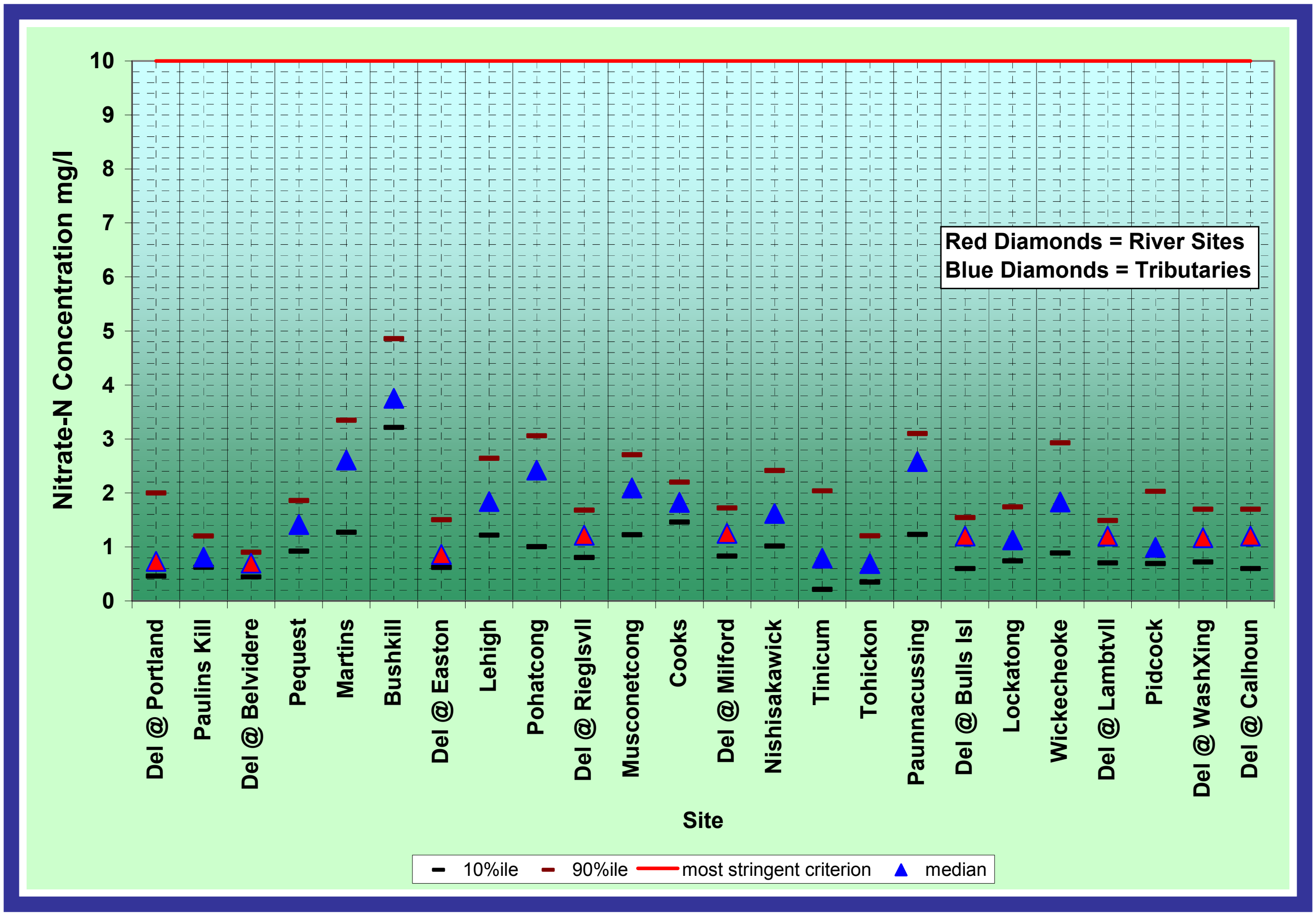


Figure 17. Lower Delaware Nitrate Concentrations, Longitudinal Plot.

There are no nitrate criteria for this reach of the Delaware River. The PA and NJ public supply criterion is 10 mg/l, a human health criterion that is far higher than EWQ (**Figure 17**). Nitrate effects upon the degree of eutrophication in the Delaware River are unknown. It is recommended that EWQ targets be established in order to prevent nutrient concentrations from rising above manageable levels.

pH

Figure 18. Median pH of the Lower Delaware River and Tributaries.

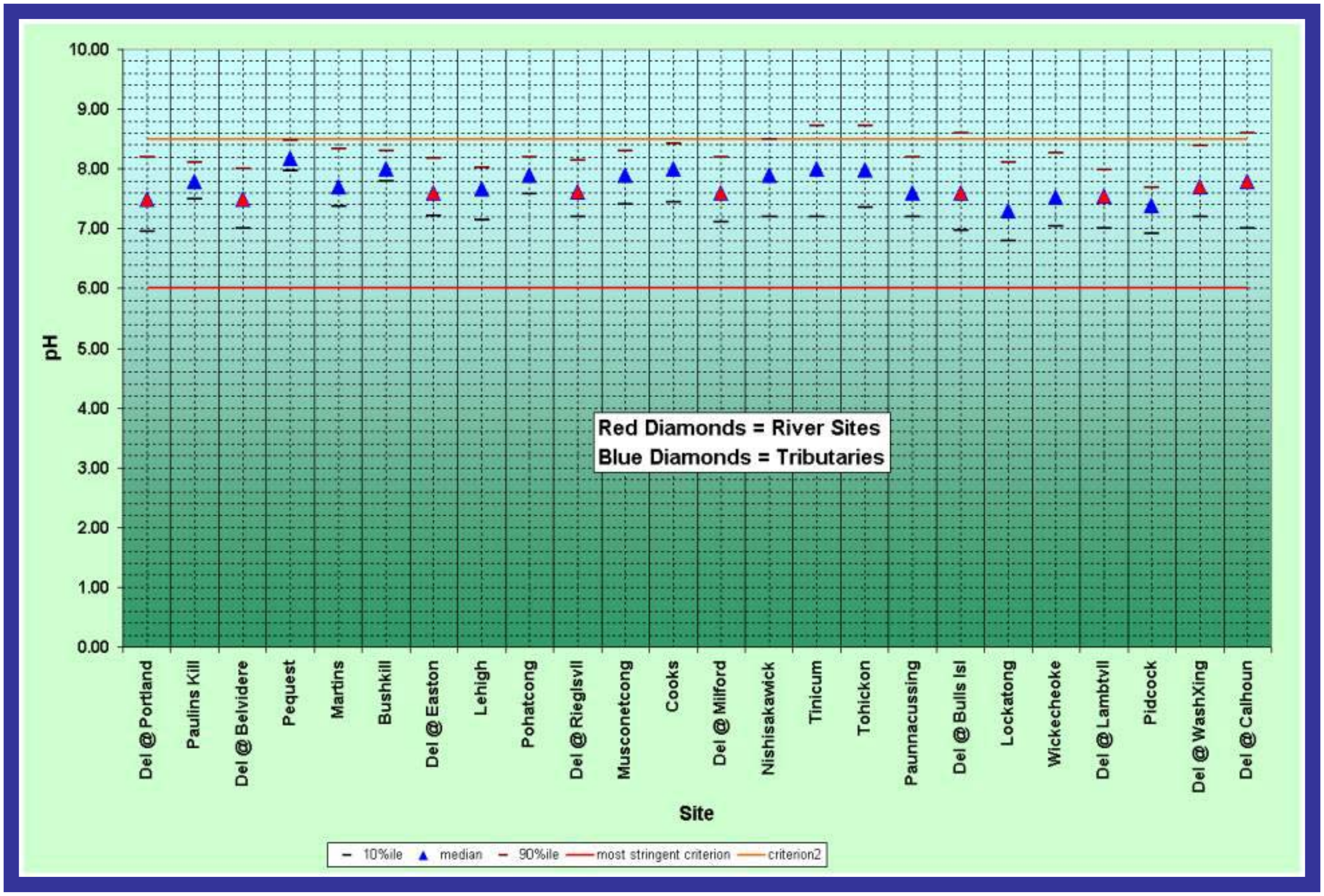
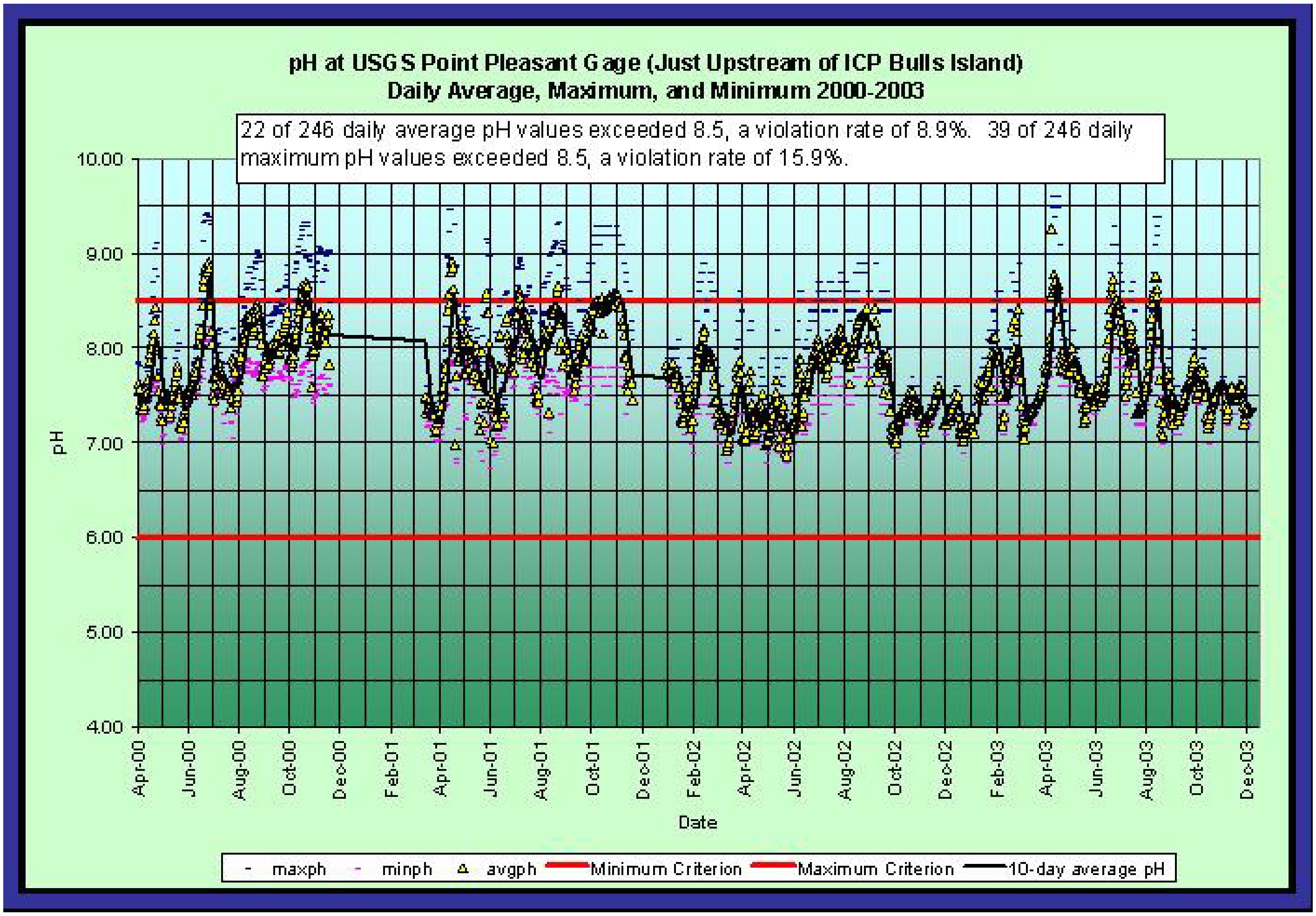


Figure 18 compares Lower Delaware pH with Stream Quality Objectives for Zones 1D-1E: 6.0-8.5 Units. About 10% of observations exceeded 8.5. These data are skewed toward daily maxima because they represent midday instantaneous measurements. pH may exceed 8.5 due to either natural conditions or nuisance aquatic plant growth. If natural conditions cause high pH, perhaps Pennsylvania's upper pH limit of 9 units better represents natural conditions in the Delaware River.

pH – Point Pleasant Continuous Monitor

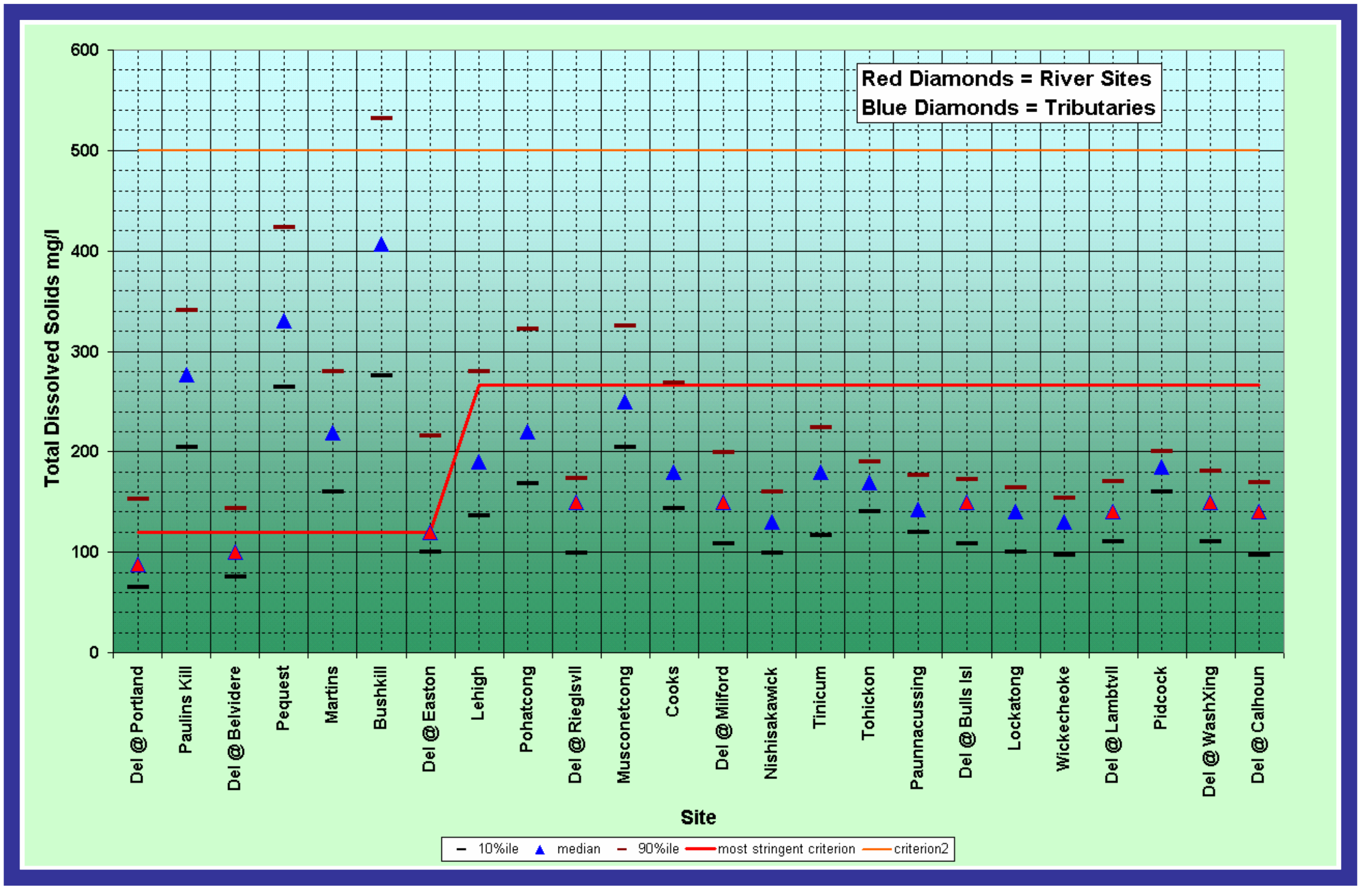
Figure 19. Daily pH at Point Pleasant Continuous Monitor, 2000-2003.



pH undergoes a daily cycle due to aquatic plant growth. Continuous data from the monitor at Point Pleasant provides information daily pH fluctuations. Figure 19 shows that 15.9% of daily maxima at Point Pleasant exceeded the DRBC criterion. By DRBC standards, pH is a problem here. Nuisance aquatic plant growth may be the cause, as large beds of Myriophyllum, Elodea, and Cladophora were observed at and upstream of this location during extended drought periods. During long low flow periods, when the river's flow is mainly supported by minimal reservoir releases, and no flood pulses are available to wash out aquatic plants, the density and coverage of rooted aquatic plants accumulates to such a degree as to accumulate fine sediments, trash, and even enable blooms of duckweed, the small floating aquatic plant normally dispersed by the river's velocity. This occurs at several locations from mid to late summer. The presence of dense mats of duckweed along the river may be an indicator of negative water quality effects of flow management policies that allow long periods of minimum flow in the river.

Total Dissolved Solids

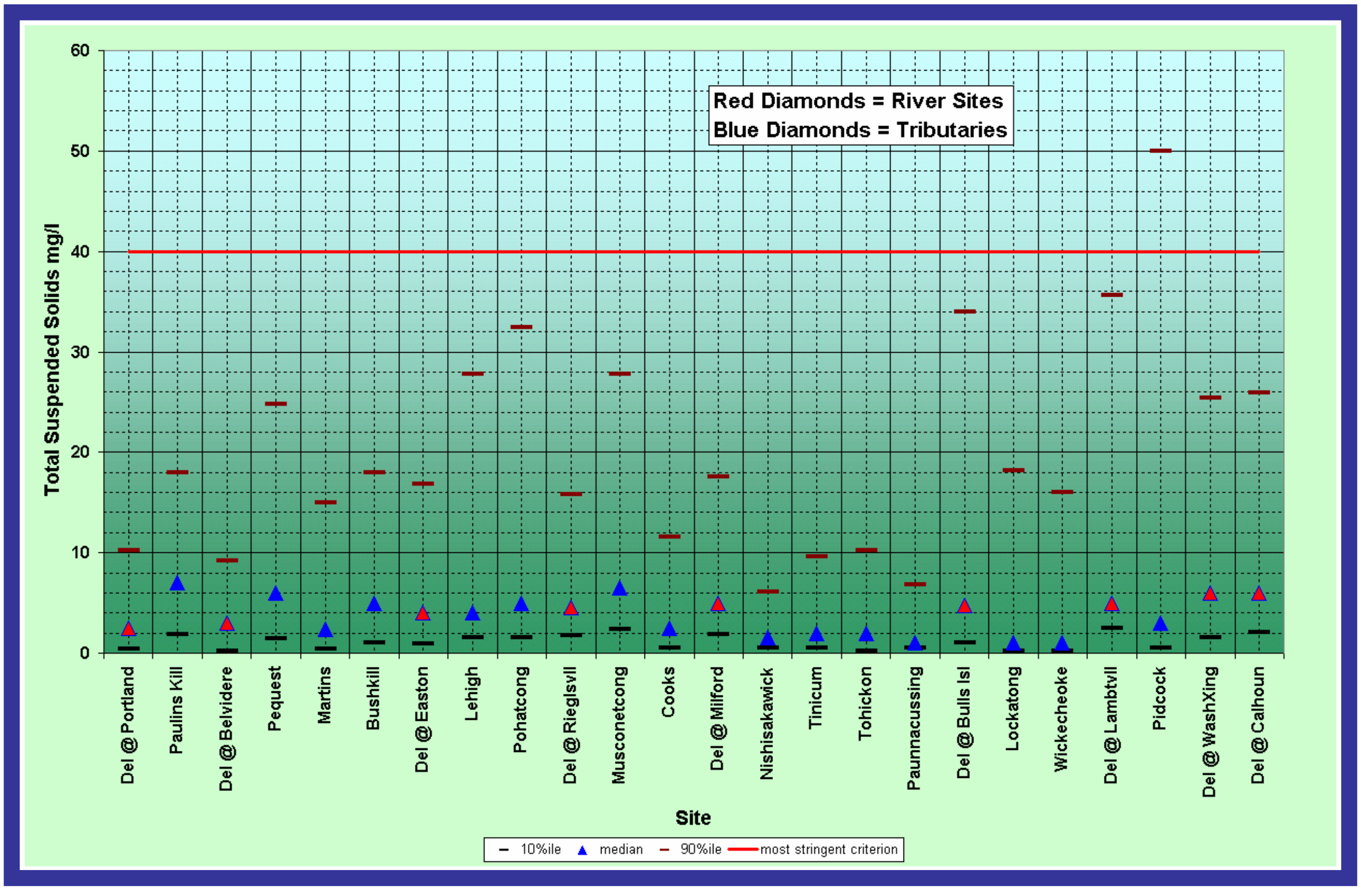
Figure 20. Total Dissolved Solids, Lower Delaware and Tributaries



More than 10% of Delaware River samples exceeded DRBC's 133% of background TDS objectives (**Figure 20**). However, this occurred only in areas of the river fed by limestone streams. It appears that the background concentration defined in the water quality regulations is not representative of natural TDS.

Total Suspended Solids

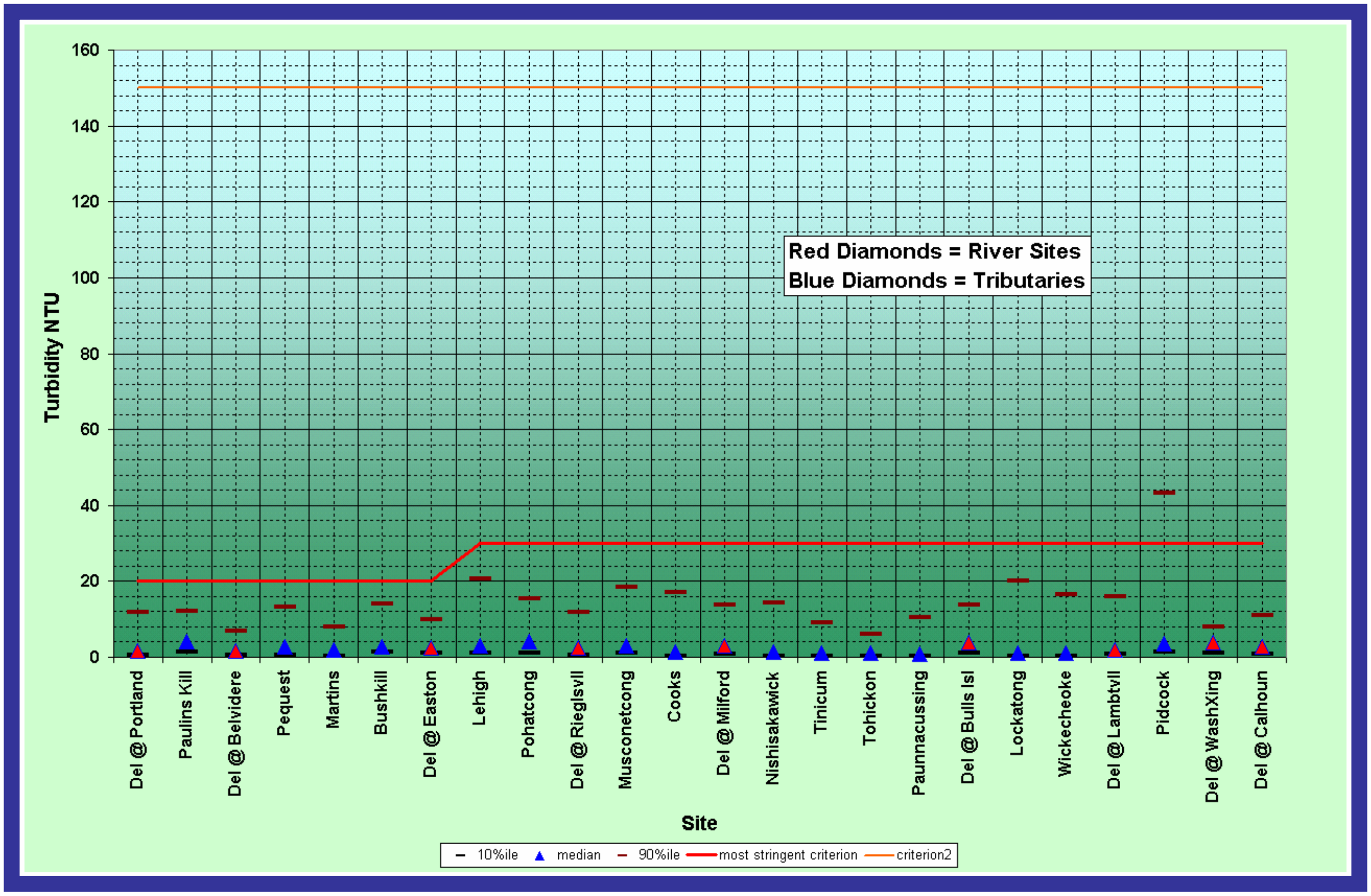
Figure 21. Total Suspended Solids, Lower Delaware and Tributaries.



Only Pidcock Creek exceeded New Jersey's most stringent criterion of 40 mg/l TSS for more than 10% of samples (**Figure 21**). At all other sites, EWQ is much better than criteria. TSS concentration is strongly associated with flow (Spearman Rank Correlation of 0.72).

Turbidity (NTU)

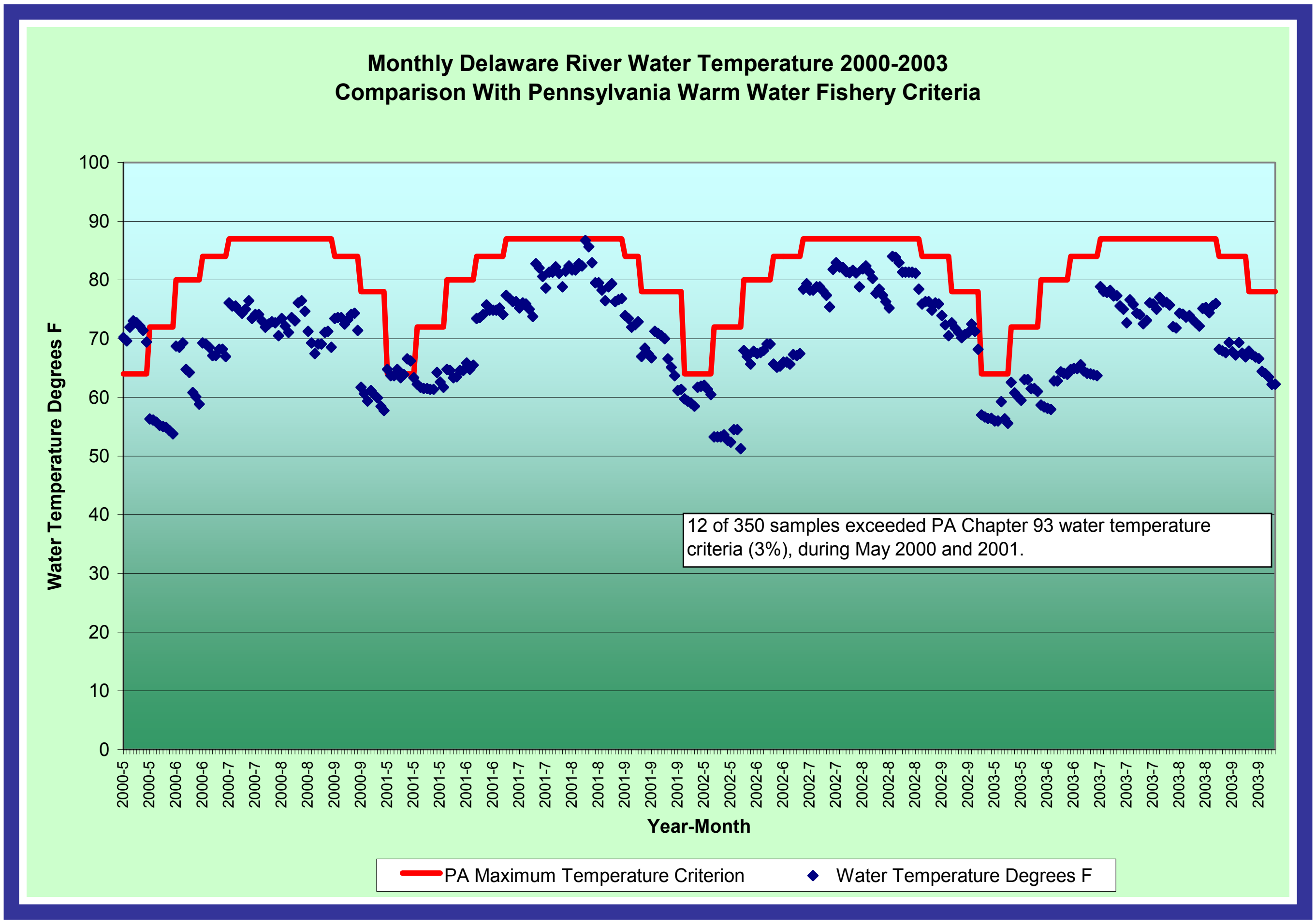
Figure 22. Turbidity in the Lower Delaware and Tributaries



Only Pidcock Creek exceeded DRBC turbidity criteria for more than 10% of samples (**Figure 22**). EWQ at Delaware River sites also meets the most stringent 15 NTU 30-day limit set for New Jersey waters. Turbidity is strongly associated with flow (Spearman Rank Correlation of 0.55).

Water Temperature – Delaware River

Figure 23. Water Temperature in the Lower Delaware River, 2000-2003



Delaware River temperature data were plotted against Pennsylvania's most stringent seasonal ambient warm water criteria. The Delaware River exceeded criteria only in May of 2000. There was an unusually hot spell that May, followed by a cooler summer and numerous high-flow events that drove water temperatures much lower than criteria. Overall, Delaware River temperature meets the most stringent Pennsylvania warm water criteria – even during a severe drought. These criteria should be adopted for the Delaware River, and are recommended as EWQ targets for Special Protection Waters rules. Water temperature is negatively associated with increasing flow (Spearman Rank Correlation of –0.58)